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UPLINK POWER CONTROL AND SOFT HANDOFF PRIORITIZATION IN MULTIMEDIA DS-CDMA

A Thesis

Submitted to the Graduate Faculty of the
University of New Orleans
in partial fulfillment of the
requirements for the degree of

Master of Science
in
The Department of Computer Science

by

Wei Shi

B.S, University of Science and Technology of China, 1996

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ABSTRACT

In the CDMA cellular networking system, power control is a very important issue because it is an interference limited system. In order to reduce the near-far problem and improve the battery life of mobile station, the transmit power of mobile stations must be controlled to limit interference. In this paper, we study the effect of power control on system performance. Different power control rates may have influence on the performance. Meanwhile, we take the consideration of different call admission control algorithm. By introducing soft handoff waiting queue and guard channel into the soft handoff algorithm, we compare the power control influence on a base case (which is similar to IS95 algorithm, but with perfect power control) and proposed call admission control algorithm. The simulation shows that increasing power control rate and combination of power control and soft handoff prioritization can greatly reduce the blocking rates and refuse rates of new/soft handoff calls, thus the system performance is improved.

Keyword: Power Control, Soft Handoff, Handoff Queue, DS-CDMA, Guard Channel, Call Admission Control

INTRODUCTION

The wireless services have expanded from voice service to the multimedia services such as voice, data, graphics, low-resolution video, etc. with the growing of the Internet. [1]-[3]. Direct Sequence Code-Division Multiple Access (DS-CDMA) has become one of the most powerful systems in the multi-media wireless communication due to its numerous advantages such as universal one cell frequency use, narrow bandwidth interference rejection, inherent multipath diversity, soft handoff capability and soft capacity limit. Because interference caused by other users can hinder these advantages, and all signals in a DS-CDMA system are sharing the same bandwidth and overlapping in time, it is essential to exercise some kind of control to maintain acceptable signal-to-interference ratio (SIR) for all users.

One critical problem with DS-CDMA is the near-far problem. This problem occurs in the absence of power control—if all mobiles were to transmit at the same power level, the mobile closest to the base station will overpower all others (since the signal power drops exponentially with the distance). To minimize the near-far problem, all mobiles will achieve the same received power levels at the base station. The target value for the received power level must be the minimum level possible for user-defined performance objectives (BER, FER, capacity, dropped-call rate, and coverage). In order to implement such a strategy, the mobiles closer to the base station must transmit less power than those far away.

Yet another reason for power control is battery life—if the mobile station were to continuously transmit at a power higher than that needed to maintain an acceptable SIR, the battery lifetime is reduced. Using power control, each mobile station may transmit using the minimum power needed for maintaining the required SIR ratio, thus conserving its battery life.

CDMA is an interference-limited system—since all mobiles transmit at the same frequency, internal interference generated within the system plays a critical role in determining system capacity and voice quality. The transmit power from each mobile must be controlled to limit interference. However, the power level should be adequate for satisfactory voice quality.

IS-95 CDMA standard also introduces the *soft handoff* scheme to use the bandwidth more efficiently. Unlike the *hard handoff* (Make-After –Break) scheme in FDMA or TDMA, a MS in CDMA can communicate with two or more base stations simultaneously when it sends soft handoff request (Make-Before-Break). A soft handoff request is more preferable than a new call request. Power control and handoff have been two significant problems for cellular wireless systems. While both problems have received considerable attention of late, the problems are not often treated in a joint manner.

The rest of this paper is organized as follows. The second section will review the relative work on both soft handoff and power control. Following the description of the power control and soft handoff in section 3 and section 4, the simulation model is discussed. Then, as a conclusion, the paper discusses the implementation and simulation results.

Related Work

As a mobile station moves around, the fading, shadowing, external interference, and other factors can continuously change its environment. Power control is to limit transmitted power on the forward and reverse links while the link quality under all conditions is maintained. Due to non-coherent detection at the base station, interference on the reverse link is more critical than it would be on the forward link. Reverse link power control is therefore essential for a CDMA system and is enforced by the IS-95 standard.

The reverse link power control includes the open-loop power control (also known as autonomous power control) and the closed-loop power control. The closed-loop power control involves the inner-loop power control and the outer-loop power control.

There have been abundant amount of works on the reverse link control as well as soft handoff schemes. In Kim, Wu, and Grandhi, centralized power control was studied, and due to the complexity of the system, centralized power control was suggested only for providing theoretical limits [8,9]. When all users could be accommodated with acceptable signal-to-interference ratios, Foschini suggested a convergent distributed-power-control algorithm to compute the required transmission power of each mobile station [11]. Jeantti presents a second-order constrained power control algorithm. This approach uses the current and past power values to determine the necessary transmission power of each mobile. Compared with the algorithm presented in Foschini, it was shown to converge at a faster rate. Convergence analysis of distributed power-control algorithms is investigated in Huang. Yates presented a framework for uplink power control in cellular radio systems.

A very important concept: Signal-to-Interference Ratio (SIR) was introduced in [12,13], and used as the basis of call admissions. Dynamic channel allocation (DCA) has been studied, based on the SIR. Both the radio propagation and the traffic loading variation were taken into consideration to evaluate the performance. Kim, Sung and Adachi introduced methodologies for capacity estimation for SIR-based power controlled system in muliple-cell, multicode and overlaid multiband CDMA systems, and investigated the effects of the voice activity factor, the required E_b/I_0 , the maximum received power, and propagation parameters on the reverse (mobile-to-base) link capacity [21,22,23]. Effect of the mobile transmit power limitation on the transmission performance is also studied in [24,25].

Naghian etc. proposed dynamic step size power control method in [16], utilizing dynamic step-size power control commands, received SIR/power, and mobile handset location assistance data. Furthermore, dynamic inter-operation between the power control, admission control, and handoff control is evolved to improve the convergence of the proposed power control mechanism.

As of soft handoff, a lot of studies had been made to improve the handoff performance using guard channel, channel borrowing and handoff queue [4,5,6,17,18,19,20]. The guard channel (GC) protocol is the most popular non-predictive channel reservation approach for handoff prioritization. The channels set aside for handoff requests are often called guard channels [4]-[5]. Queue of handoff requests is another effective way to reduce the handoff blocking rate without increasing the blocking rate of the new call very much [5], [6]. Jiang's work has focused on the hybrid scheme of using the Guard Channel and Handoff queue together in the multimedia CDMA wireless system, especially for the soft handoff requests [7]. With the using of guard channels, separate handoff queues for voice calls and data calls, and the prioritization of handoff calls over new calls, the QoS (quality of service) has been improved in terms of blocking rates.

Few works have taken power control and soft handoff CAC together into consideration. Combined downlink power control and handoff design for cellular communication systems using a hybrid system framework was discussed in [14]. In [15], Park, Sung etc. discussed how to the uplink transmit power of a MS during soft handoff in order to reduce the error probability of downlink transmit power control command bit without macro diversity gain at the BS. The uplink transmit power control was based on uplink transmit power control commands from all base stations belonging to the active set.

The paper will adapt the call admission algorithm proposed in Jiang's thesis to compare with the IS-95 standard, with power control in both cases. The paper will discuss the effect of different power control frequency on the blocking rates of calls, and the comparison of power control effects between different call admission algorithms.

Simulation Model

1. Power Control

According to the IS-95 standard, power control for DS-CDMA consists of reverse link open-loop power control, reverse link closed-loop power control, and forward link power control.

Primarily, reverse link open loop power control is a function of the mobile stations, while the base stations play an active role in the reverse link closed-loop power control and the forward link power control. Power control for the reverse link is a combined technique consisting of closed-loop and open-loop power controls. Also, it is a fixed step size algorithm and strength-based distributed algorithm. The goal of open-loop power control is the estimation of a path loss and a loss due to shadowing between the base and the mobile station. According to this process, the mobiles transmit the initial power control signal.

Closed-loop power control is used because multipath fading in a reverse and a forward DS-CDMA link is an independent process. Every base station measures the received signal-to-interference ratio (SIR) from each mobile station. The measured SIR is compared to the desired SIR for that mobile station and a power adjustment command is sent to the mobile station. This power adjustment command is combined with the mobile station open-loop estimate to obtain the final value of the mobile station transmit power. This command has the fixed step size of 0.5dB and it is transmitted at a rate of once every 1.25ms. The base station measures the signal quality (BER) and based on that determines the desired SIR for specific mobile station.

The implementation of power control shall allow the base station send a power control command to each mobile station in it and adjust the transmit power of each mobile station separately.

2. Soft Handoff

Soft handoff mechanism is utilized in an IS-95 CDMA system. Each MS measures the signal strength from its surrounding BSs. The PN offsets of the BSs serve as the identification numbers for the BSs. When an adjacent base station's pilot strength is strong enough to establish a communication link, the base station's PN offset is stored in the mobile station's Active Set (AS). With lower signal thresholds, the MS also maintains a Candidate Set and a Neighborhood Set. When an MS is undergoing a soft handoff, more than one pilot is stored in its Active Set. Depending on the number of base stations involved, 2-way or 3-way soft handoffs can occur, until the communication like between the mobile and one base station is firmly established. The "ping-pong" effect (constantly switches between base stations at the border), common phenomena in hard handoff, is avoided under this "make before break" strategy. Thus, the signal quality and service reliability is substantially improved through soft handoff.

The soft guard channel (GC) is introduced to prioritize soft handoff calls. In CDMA cellular systems, a certain amount of system resources is reserved exclusively for soft handoff calls. When a soft handoff request comes in the station, if the system resource is not enough to accept this call, this call can request reserved guard channel, while the new calls cannot use the reserved system resource.

To prioritize the soft handoff requests, separate handoff queues are introduced for voice handoff requests and data handoff requests. If the common resource shared by both new calls and soft handoff requests cannot the meet the requirement of a new coming soft handoff request, the base station will use the soft guard channel. If this soft handoff call still can not be admitted, it will either enter the voice/data handoff queue of the target cell or get blocked. Those calls waiting the voice/data handoff queue can get more chances to send soft handoff request to the target cell again unless it is out of this cell or terminates. Since the calling time of voice calls is generally much shorter than that of data calls and occupies less system resources than the data call does, the voice handoff calls in the voice handoff wait queue have higher priority to the data handoff calls in the data handoff wait queue. Data handoff calls in data handoff wait queue can only send handoff requests again to the target cell after the voice handoff queue is empty.

3. CDMA Cellular System Scenario

A hexagonal geometry is often used to illustrate the cell (Fig. 1). A target cell can be partitioned into two zones: Core Zone (CZ) and the Soft Handoff Zone (SHZ). With respect to the base station in the target cell, the area immediately adjacent to the SHZ is called the neighborhood zone (NZ). To simplify the simulation, we assume that an MS can only communicate with at most two base station simultaneously, which means the active set can only be 1.

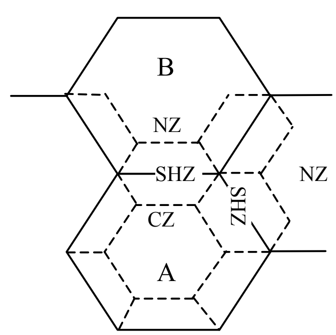


Fig 1. Hexagonal geometry for a cell

Define σ to represent the ratio of the area of CZ to the area of the target cell:

$$\sigma = CZ / (CZ + SHZ/2)$$

When a mobile station crosses the boundary of the layout, a wrap around method should be used to deal with the mobile station's location and put it back to system layout. For instance, cell 49's neighbors are cell 0, cell 6, cell 55, cell 48, cell 42, and cell 50. When an MS crosses the boundary of cell 49 and gets out of the 56-cell layout, it can be wrapped around and it gets in cell 0 again, so the layout can be spread out infinitely. The layout of the system is illustrated in Fig. 2.

4. New call generation

The generation of new calls is assumed to be a Poisson process and the interval times for voice and data are assumed to be independent, with rate λ_{nv} and λ_{nd} respectively. The location of a new call is decided by normal distribution. The percentage of new data call (β) is assumed to be fixed related to the new voice call, and the mean target cell dwelling time for voice and data call is τ_v and τ_d.

5. Radio Propagation Model

Generally, the radio propagation model for DS-CDMA cellular systems is thought to be a lognormal distribution of shadowing, with its mean the path loss of the αth power of the distance [2]. If a mobile is at distance r from a base station, the average received field strength $\Gamma(r)$ in real value can be expressed as:

$$\Gamma(r) = 10^{\xi/10} r^{-\alpha} \quad (1)$$

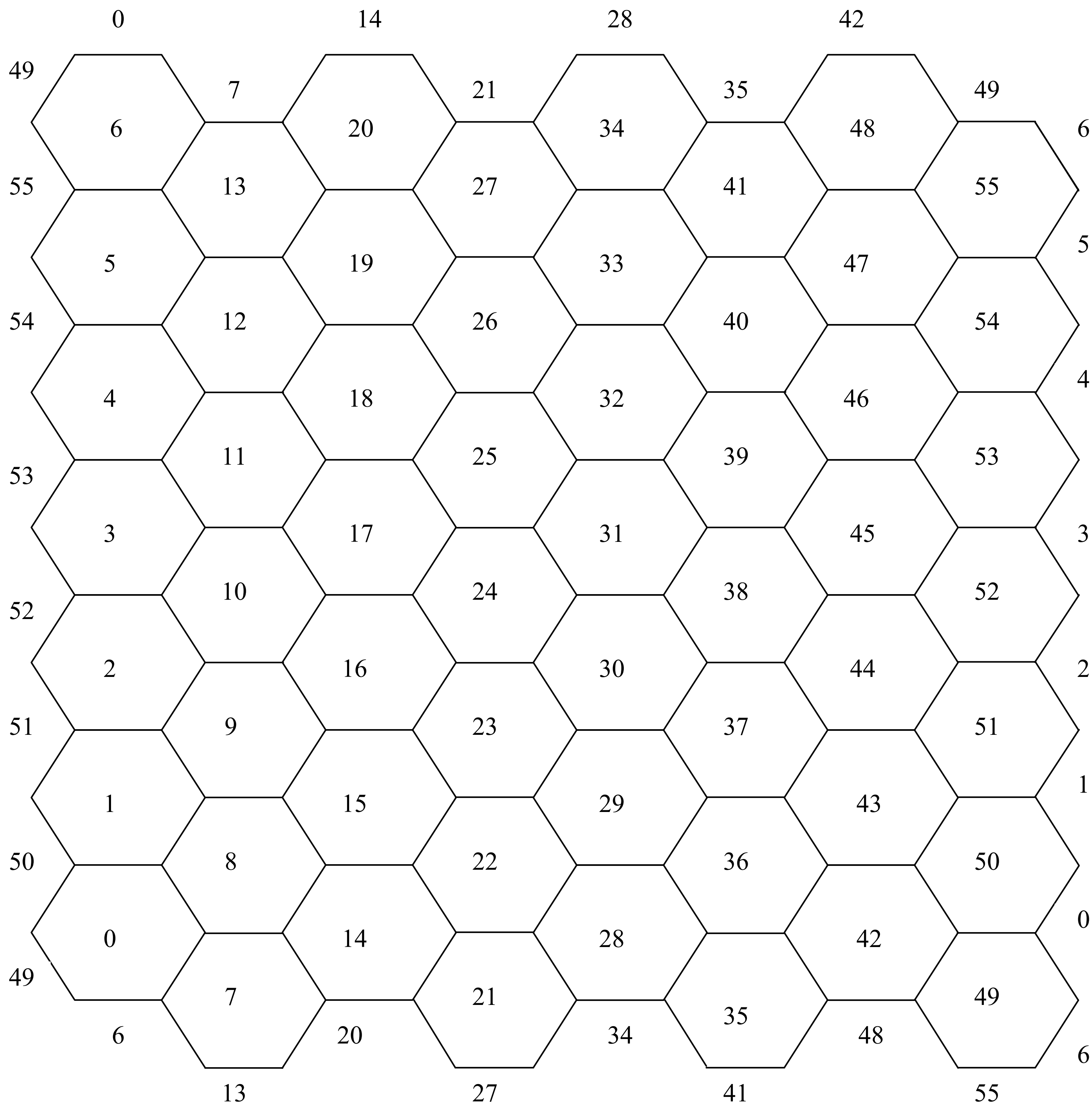


Fig.2 System Layout with 56 cells

Where ξ in decibels has a normal distribution with zero mean and standard deviation of ψ, which is independent of the distance and ranges 5~12 dB with a typical value of 8 dB. Typical values of α in a cellular environment are 2.7 ~ 4.0 [5].

6. System Resource Management

Because DS-CDMA is interference-limited, there is a practical limit on the number of simultaneous users in a cell to control the interference among users having the same pilot signal. In [26,27,28], the maximum number of current users is restricted by the Signal to Interference Ratio (SIR). The value for SIR depends on the different type of media transferred via the wireless network. If the user can endure the high interference, the cell then can accept more users. As a result of [19], the system capacity bound of CDMA system supporting voice and data traffics in the reverse link is expressed as:

$$\sum_{i=0}^{N_v} \gamma_{vi} + \sum_{j=0}^{N_d} \gamma_{dj} \leq 1 \qquad (2)$$

Where

$$\gamma_v = \frac{\alpha}{\frac{W}{R_{v_{req}}} \left(\frac{E_b}{N_o}\right)_{v_{req}}^{-1} \left(\frac{1}{1+f_k}\right) 10^{\frac{Q^{-1}(\beta)}{10}\sigma_x - 0.012\sigma_x^2} + \alpha}$$

$$\gamma_d = \frac{1}{\frac{W}{R_{d_{req}}} \left(\frac{E_b}{N_o}\right)_{d_{req}}^{-1} \left(\frac{1}{1+f_k}\right) 10^{\frac{Q^{-1}(\beta)}{10}\sigma_x - 0.012\sigma_x^2} + 1}$$

γ_v and γ_d are the amount of system resources that are used by one voice and one data user, respectively. N_v and N_d denote the number of active users in the voice and data service groups respectively, W is the allocated frequency bandwidth, σ_x is the standard deviation of the received SIR that indicates the overall effect of imperfect power control, α is the voice activity factor, and $(E_b/N_o)_{vreq}$ and $(E_b/N_o)_{dreq}$ are the required bit energy-to-interference power spectral density ratio for the voice and the data service groups respectively. f is the other cell interference factor defined as the ratio of the intercell interference from inter cell to the intracell interference from intra cell, $(\frac{1}{1+f})$ is the average value of frequency reuse factor, and Q^{-1} is the inverse Q function defined as $Q_x = \int_{-\infty}^{x} (1/\sqrt{2\pi} e^{-y^2/2}) dy$.

The formula to calculate the f is the following:

$$f_k = \frac{\sum_{i=0}^{5} \sum_{j=0}^{N_i} I_{jk}}{\sum_{t=0}^{N_k} I_{tk}} \qquad (3)$$

Where

$$I_{jk} = P_j * \Gamma(r_{jk}) = P_j * 10^{\xi/10} r_{jk}^{-\alpha}$$

r_{jk} is the distance from the mobile station j to the base station center; N_i is the number of the mobile station in the base station i, which is the neighbor cell of the BS k.

QoS requirements of each traffic includes the required information bit rate (R_{req}), the required bit energy-to-interference power spectral density ratio ($E_b/N_o)_{req}$, the traffic active factor (α) and the system reliability requirement ($P_r(SIR > SIR_{req}) = \beta\%$, where $SIR_{req} = (E_b/N_o)_{req}R_{req}/W$). Hence, users in the same service group have the same QoS requirements.

The inequality of Equation (2) is the sufficient and necessary condition that satisfies the system QoS requirements and indicates that calls of different services take different amount of system resources according to their QoS requirements. For voice and data calls, a data call generally consumes more system resources than a voice call.

Power Control Schemes

If the interference from other cells is not taken into consideration, there will be calls dropped unexpectedly for the neighboring cells. In order to reduce this risk, the variable, other interference factor *f*, is introduced and this make the inference from neighboring cells included in the resource allocation to every MS.

The inner closed loop power control of reverse link is used in this paper. Based on SIR measurement of each mobile station in a base station, the transmit power of every mobile station is monitored and adjusted to reduce the total transmit power of the system and the interference in the system.

1. Without Power Control

In the equation (3), to calculate the other interference factor *f*, if there is no power control method applied (in this case, all mobile stations are assumed to transmit at the same power level), the equation for interference is:

$$I_{jk} = P * \Gamma(r_{jk}) = P * 10^{\xi/10} r_{jk}^{-\alpha}$$

Replace this into equation (3),

$$f_k = \frac{\sum_{i=0}^{5} \sum_{j=1}^{N_i} r_{jk}^{-\alpha}}{\sum_{t=1}^{N_k} r_{tk}^{-\alpha}}$$

Thus, we can use equation (2) to calculate the resources for each call.

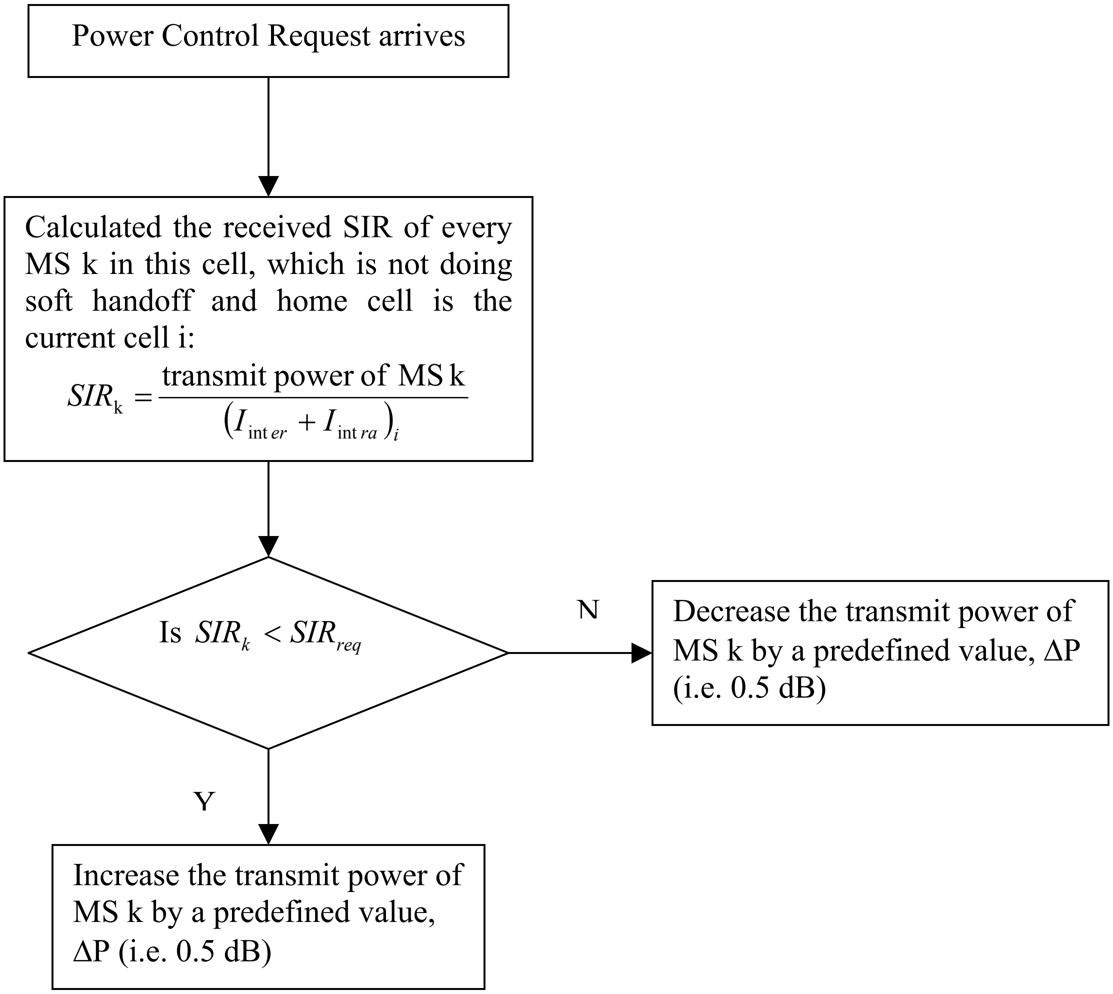
2. With Power Control

In IS-95 CDMA system, inner closed loop power control algorithm is implemented for reverse link. The power control rate is 800 Hz, which means the base station will measure the received SIR of each MS in it every 1.25 ms, and compared the measured SIR to the required SIR of this service. If it is lower than the required value, the BS shall send a power-up command to the MS and have the MS's transmit power increased by a fixed step size, i.e. 0.5 dB. If the received SIR is above the required value, the BS shall send a power-down command to the MS and have its transmit power decreased by a fixed step size (0.5 dB). Fig. 3 is a flow chart of the power control process of those active MS's who are not doing soft handoff.

Because the BS sends power control command to every MS inside of it independently, the transmit power of MS will differ from each other eventually. Hence, the equation to calculate interference and the other interference factor *f* will become as below:

$$I_{jk} = P_j * \Gamma(r_{jk}) = P_j * 10^{\xi/10} r_{jk}^{-\alpha}$$

Replace this into equation (3) to get the value of *f*, the power P_j can not be cancelled out.

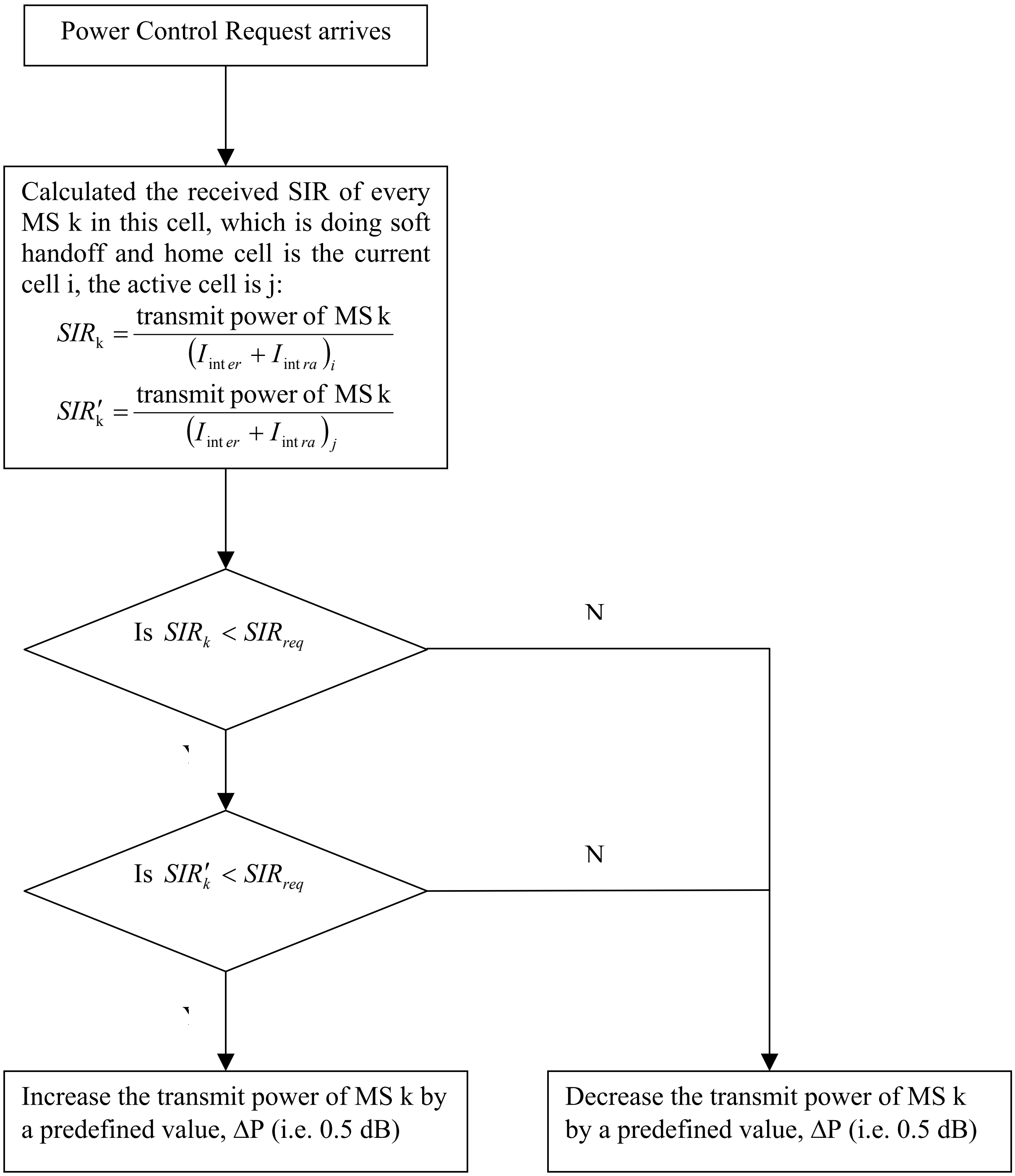


Voice call: $SIR_{req} = \left(\frac{E_b}{N_0}\right)_{req}\left(\frac{R_{v\_req}}{W}\right)$, Data call: $SIR_{req} = \left(\frac{E_b}{N_0}\right)_{req}\left(\frac{R_{d\_req}}{W}\right)$

Fig. 3 Flow chart of uplink power control for non soft handoff mobile stations

3. Power control during soft handoff

Controlling the transmit power of a mobile station (MS) during soft handoff is very important because the mobile may be located far from its controlling base stations (BS's), and the uplink and downlink transmit power for the MS is larger than for mobiles located near the controlling BS's.



Voice call: $SIR_{req} = \left(\frac{E_b}{N_0}\right)_{req} \left(\frac{R_{v\_req}}{W}\right)$, Data call: $SIR_{req} = \left(\frac{E_b}{N_0}\right)_{req} \left(\frac{R_{d\_req}}{W}\right)$

Fig. 4 Flow chart of uplink power control during soft handoff

In the conventional schemes, which are also used in this paper, for uplink transmit power control during soft handoff, an MS decreases the transmit power of uplink channel whenever the received power control command from at least one BS belonging to the active set is *power-down*, and increases the transmit power only when all received power control commands from all BS's belonging to the active set are *power-up*.

When an MS is in soft handoff, it receives uplink transmit power control commands from the two base stations it communicates with. Assume that two base stations, BSA and BSB, are the controlling BS and the target BS in the MS's active set. Each transmit power control command can be one-bit information of ”0” corresponding to *power-up* or ”1” corresponding to *power-down*. Most of conventional CDMA systems including cdmaOne, cdma2000, and WCDMA transmit one-bit power control command per time slot for uplink and downlink closed loop transmit power control.

If both of the two power control commands from the two BS's involved in the soft handoff are “0” (*power-up*), then the uplink transmit power of this MS is increased by a predefined value (i.e. 0.5 dB). If both of the commands are “1” (*power-down*), then the uplink transmit power of this MS is decreased by a predefined value, i.e. 0.5 dB. If either of the two commands is “1” (*power-down*), the uplink transmit power of this MS is decreased by a predefined value. In a word, An MS determines the real power control command based on a Boolean OR operation of the received commands from the two BS's involved in the soft handoff.

The flow chart in Fig. 4 describes the process of power control process of those mobile stations during soft handoff.

4. Call Admission Control (CAC) Algorithm

CDMA systems are interference-limited and based on equation (2) and (3), whether a call can be accepted or not is constrained by the minimum signal to interference ratio (SIR) in the target cell. Interference evaluation is essential to the resource allocation. The resources a call can get depend not only on the target cell's interference (intra-cell interference) but also on that of the neighboring cells (inter-cell interference). The total interference experienced by a mobile is composed of two parts: **intra-cell interference** and **inter-cell interference**. There are two kinds of interferences: uplink interference and downlink interference. Uplink interference is the interference from the mobile stations to the base station, and downlink interference is the interference from the base stations to the mobile station. Fig. 5 shows the scenario of uplink interference in a cell.

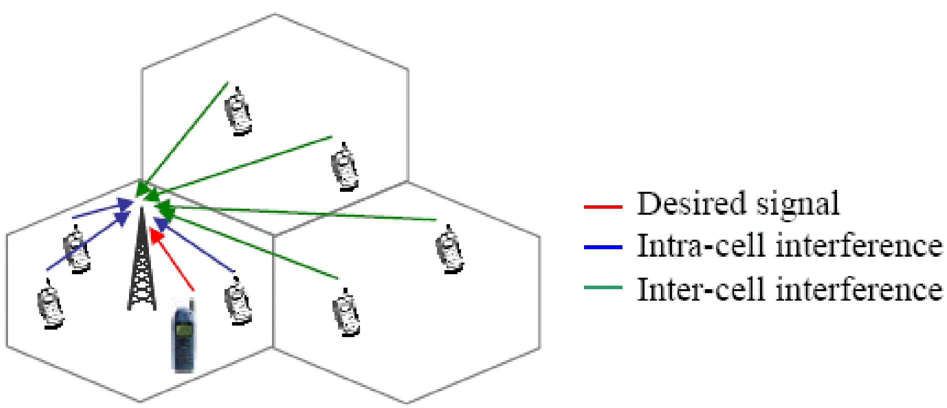


Fig. 5 Uplink interference

In the uplink, to a certain mobile, the intra-cell interference comes from all the other mobiles served by the same BS; the inter-cell interference is composed of all the signals received from all the mobiles in other cells other than the mobile's serving cell, as shown in Figure 5. Therefore, in the uplink, the interference experienced by a certain mobile is affected whenever a new call or a soft handoff call gets admitted into this cell. Thus, the uplink interference is more complicated and important to mobile stations than the downlink interference, since there is only one base transmitter in a cell and it is fairly easier to control the downlink transmit power from the base transmitter in the case of downlink interference.

Based on the distance between the mobile station and its home base station, the received transmit power of a mobile station at the base station becomes fader with its longer path to its base station, which is path loss. Without power control, the mobile station closer to the base receiver will overpower other mobile stations. It is necessary to control the mobile stations' transmit power to maintain the QoS (i.e. SIR) at a required level. Moreover, the more system resource one mobile station needs, the stronger interference this mobile station causes to other mobile stations. So data calls cause more interference than voice calls.

When processing new call requests, the traffics of the target cell and its neighboring cells are evaluated to get the parameter f as the other interference factor. Based on the result of f, the resources required by the incoming MS (voice/data) can be calculated using the two equations (2) separately. If the sum of the resources allocated to all the existing calls would not exceed the THRESHOLD variable, which is set as the total system resources excluding the reserved guard channel, the incoming new call is admitted to the target cell. Otherwise, the new call is blocked. Because the guard channel is exclusively reserved for handoff calls, the new calls cannot use it.

In the case of soft handoff, the two different types of handoff calls, voice and data, will have different priorities. Because voice calls last much shorter in time and need less system resources than data calls, the voice handoff calls have higher priority over the data handoff calls in the simulation in order to improve the whole handoff performance.

Because of the assumption that only 2-way soft handoff is considered, each mobile station can have at most one base station in its active set, and once the soft handoff is successful, it will not send a soft handoff request again to the target cell. For the target cell, when a soft handoff call arrives, firstly check the traffic of the target cell and its neighboring cell by calculating the other interference factor f. The bigger f is, the more traffic in the target cell. Then, the system resource this handoff call needs can be calculated based on the parameter f. One of the two base stations that the soft handoff call communicates with is this call's controlling base station; another one is its alternative base station. The received pilot strengths from these two base stations decide which base station is the handoff call's controlling BS. This call occupies more system resource in the controlling base station than in the alternative base station. Like the case of new calls, if the sum of system resources consumed by all the existing calls in the target cell does not exceed the THRESHOLD (the system resource with the reserved guard channel excluded), the target will admit this handoff call; otherwise, check the reserved resource (soft guard channel) and determine whether the resource is enough for this handoff call. If yes, the call is admitted; otherwise, the target cell will try to put this handoff call into its voice handoff queue or data handoff queue based on this call's type. If the handoff queue of this call's type is not full, this call is put into the queue; otherwise, this call is blocked. The handoff calls waiting in a queue will get another chance to be accepted by the target cell, thus, the queue must be checked periodically. If this call in waiting queue is terminated before it gets another chance to be accepted and it already crosses the boundary of its original base station, we say this call to be refused. If this call isn't terminated, we need to find out if this call exceeds the border of its current controlling base and enters the target cell without obtaining the required channel, this call definitely will be dropped. The number of refused handoff calls will increase by one. If this call is still in the soft handoff area and not terminated, we need to check if this call is time out (the time this call has been waiting in the queue exceeds the preset range). If yes, this call is one of the refused handoff call. Otherwise, this call is able to send another soft handoff to the target cell again. For data handoff calls in the data waiting queue, if it is still alive, it can send another handoff call only when the target cell's voice handoff queue is empty. Otherwise it will remain in the data handoff waiting queue.

Numerical Results and Discussion

The base case of our simulation is similar to the IS95 algorithm, but it assumes that no power control is implemented in the base case, all mobile stations will have same transmit power. During the whole simulation, the radius of each cell is 1000 meter; the system scenario is a 7 x 8 cellular layout with wrap around. New calls arrive according to a Poisson process and are homogeneous among all cells. The duration of each generated voice or data call is exponentially distributed with a mean of 180s or 300s, respectively. The average speed of voice MS is 18 m/s and the maximum speed is 24 m/s, so is the data MS. The power control rates, the ratio of soft handoff area to the whole base station area, are the parameters we are going to do some study on. For other parameter, they are listed in the following table:

Table 1. Parameter Value for the simulation model

Parameter	Symbol	Value
Allocated frequency bandwidth	W	1.25Mbps
Required bit transmission rate for voice traffic	R_v	9.6kbps
Required bit transmission rate for data traffic	R_d	19.2kbps
Required bit energy to interference power spectral ratio for voice traffic	$(\frac{E_b}{N_o})_{v_{req}}$	7dB
Required bit energy to interference power spectral ratio for data traffic	$(\frac{E_b}{N_o})_{d_{req}}$	7dB
System reliability requirement	β	99%
Standard deviation of received SIR	σ_x	1dB
Voice activity factor	φ	3/8
Path loss coefficient	α	3
Initial transmit power of mobile station	P	1 (0 dB)
Power control step	*PC_STEP*	0.5-1.5 dB

Simulation results:

Firstly, we consider the effect of the power control rate. The simulation is done separately on base case with power control and the proposed call admission algorithm (PCA, with waiting queue and guard channel) with power control. As of the case with handoff waiting queue and guard channel, the length of the voice handoff waiting queue was set to 2, the length of the data handoff waiting queue was set to 4, and the soft guard channel was set to 0.05 (which means 5% of the system resource was reserved for soft handoff calls). The simulation results are evaluated in term of the new voice/data call blocking rate, the voice/data soft handoff refuse rate, and the voice/data soft handoff blocking rate.

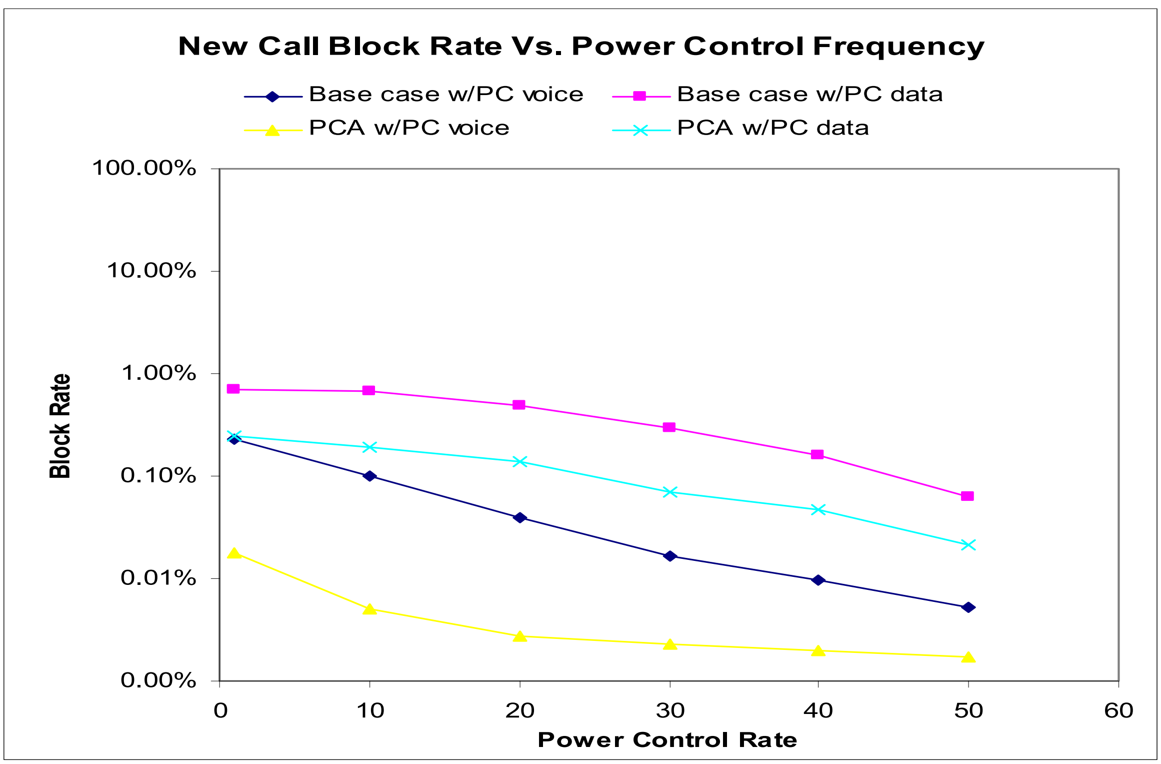


Fig. 6 New voice/data blocking rate in IS-95 and proposed CAC algorithm

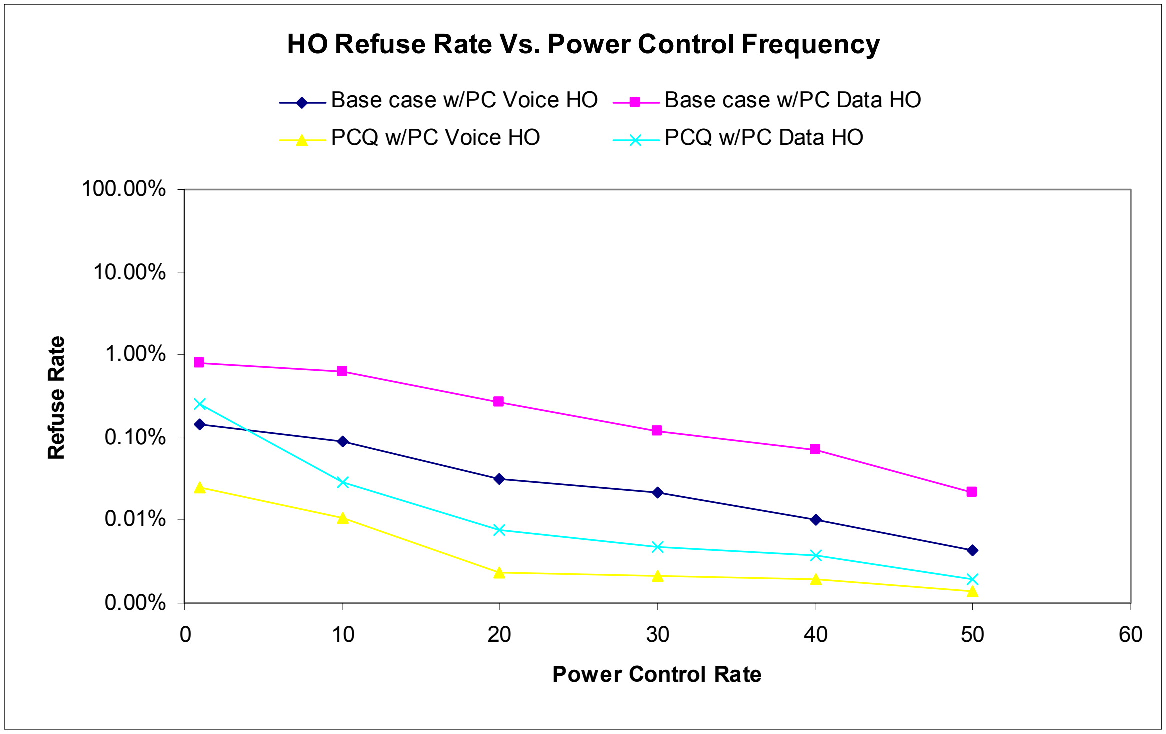


Fig. 7 Voice/Data handoff refuse rate in IS-95 and PCA algorithm

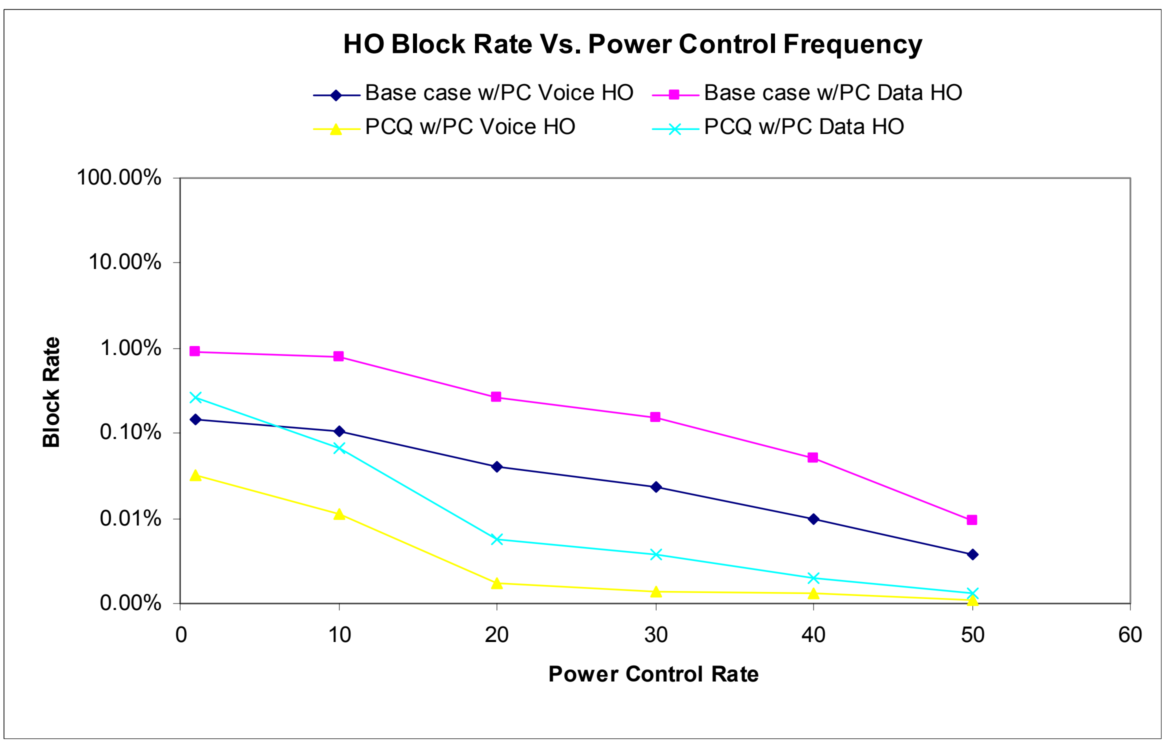


Fig. 8 Voice/Data handoff block rate in IS-95 and PCA algorithm

Fig. 6-8 describes the effect of power control rate on the blocking rates and refuse rates. As the power control rate goes higher, the new call blocking rate, the soft handoff refuse rate, and the soft handoff blocking rate decreases accordingly. From all the figures above, it shows that if the power control rate is high enough, (higher than 20 Hz), the new call blocking rate and the soft handoff refuse/block rates all decrease to a very low level. Since the power control scheme is SIR based, the BS will measure the received transmit power from every MS, compare it to the required SIR value, and send power control command to MS accordingly. The higher the power control rate is, the quicker the MS's transmit power is adjusted towards the required level; the quicker the interference is decreased. Thus, more system resource is available to new call or soft handoff calls. Hence, the new call blocking rate, the soft handoff refuse rate and the soft handoff blocking rate shall be reduced. This explains the quick drop shown in the figures above.

In Fig. 7 and Fig. 8, we can also find that the soft handoff refuse rate and blocking rate in IS-95 algorithm with power control are higher than those in proposed algorithm (with soft handoff queue and guard channel) with power control. This is due to the reason that the soft handoff calls are given the priority over new calls and more system resource is reserved for soft handoff calls with the use of handoff queues and guard channels, thus, it gets easier for soft handoff calls to get admitted during soft handoff in the proposed call admission algorithm.

However, when the power control rate is getting higher, the decreasing of block/refuse rates of new/soft handoff calls is slowing down. Because as the power control rate increases, the transmit powers of existing mobile stations have reached a relatively stable level, which leads to a relatively stable interference level. The effect of other cell interference ratio on the power control scheme becomes weaker, which responds in the figures above, the curves become flat eventually.

Considering the time the simulation takes and the block rate drops with the increase of power control rate, the rate of 20 Hz is adopted in the following simulation, although the power control rate in practice DS-CDMA systems is 800 Hz or higher (depends on the 2G or 3G algorithm).

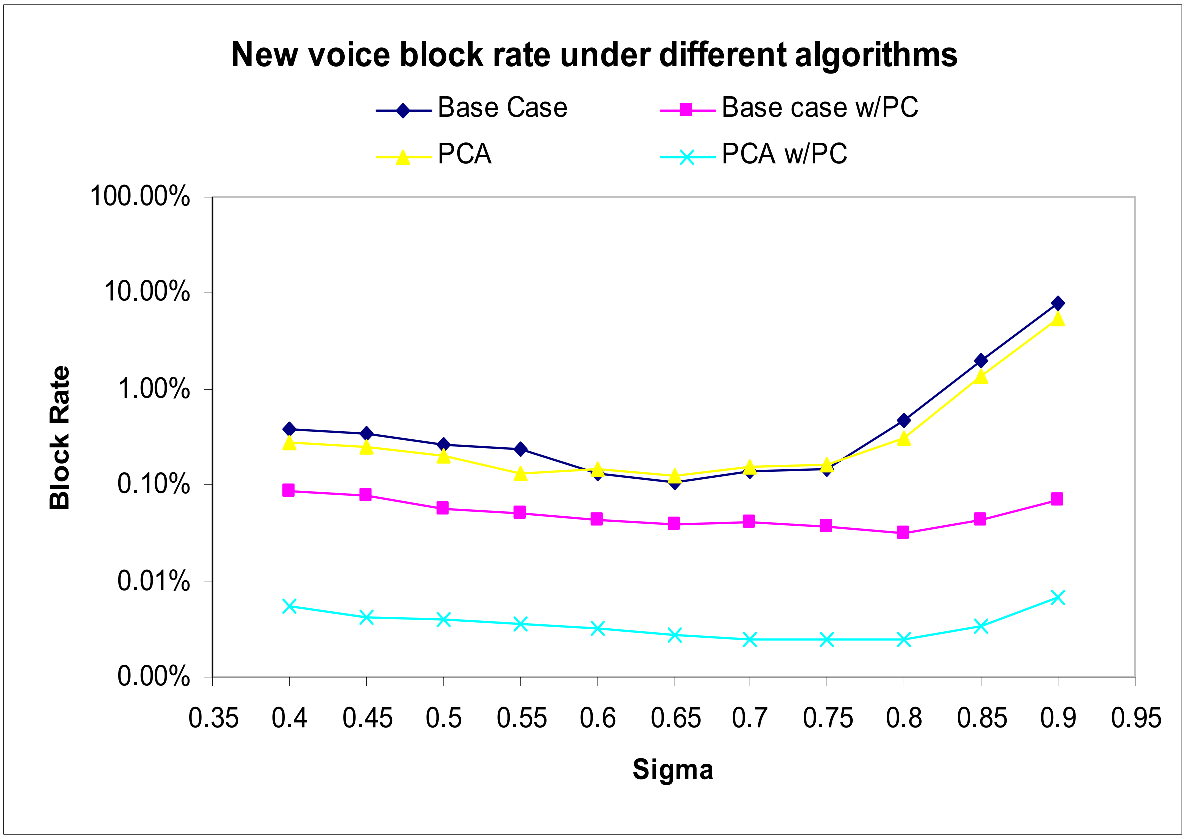


Fig. 9 New voice block rate under different algorithms

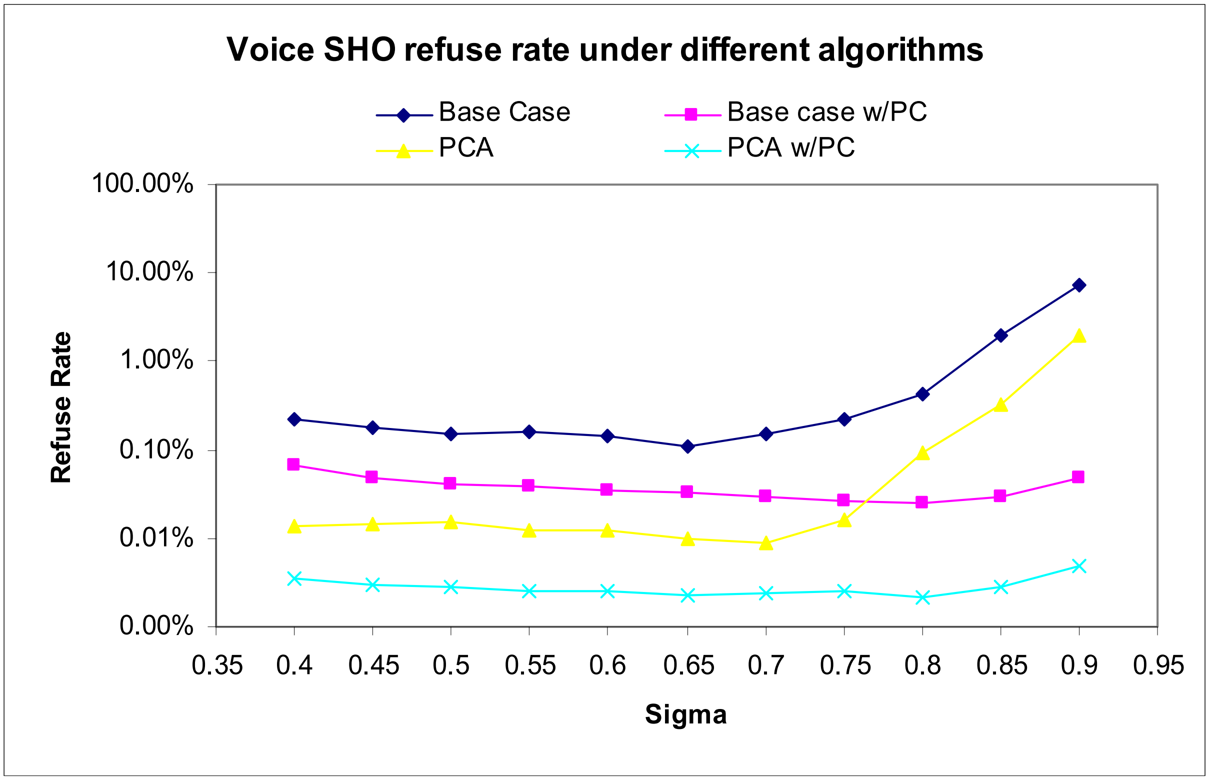


Fig. 10 Voice SHO refuse rate under different algorithms

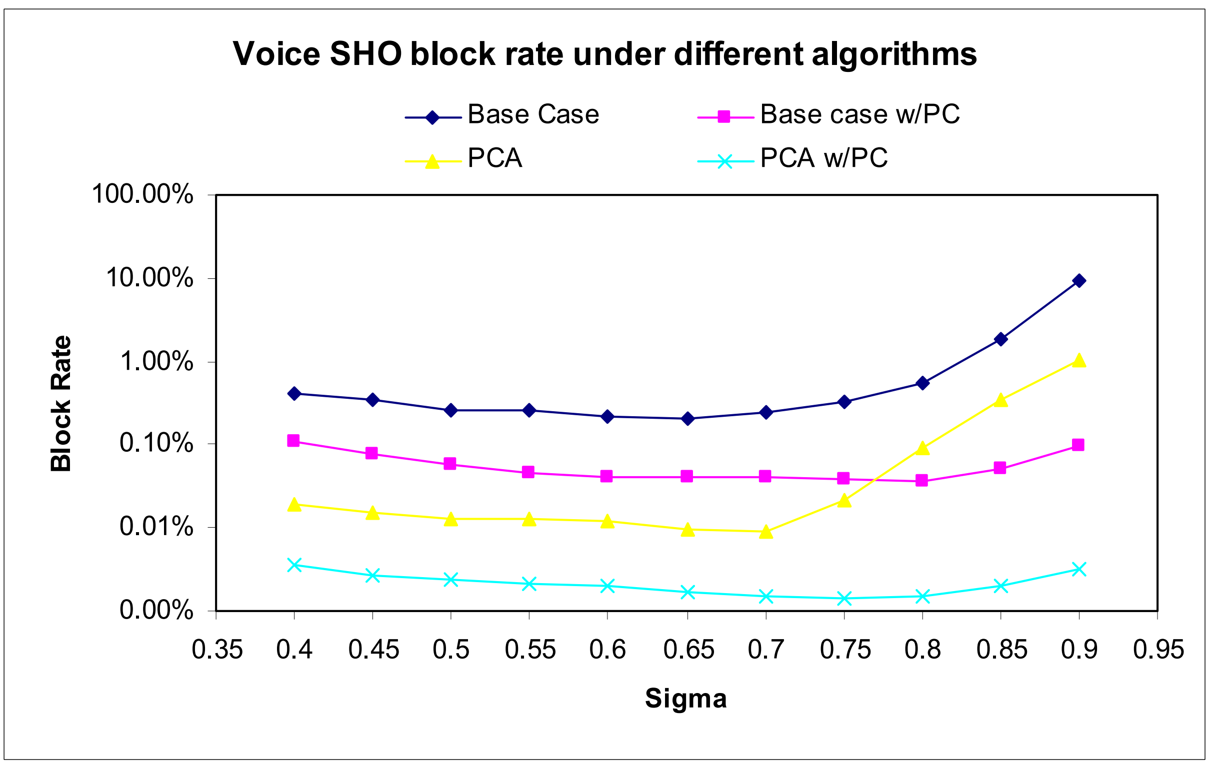


Fig. 11 Voice SHO block rate under different algorithms

Figures 9-11 describe the performance of voice calls (new voice calls and soft handoff voice calls) under different situations. The base case of the comparison has the same call admission algorithm as the IS-95 algorithm, but not including power control scheme; while IS-95 algorithm itself includes power control scheme. PCA represents the proposed call admission algorithm, which does not consider the power control. PCA w/PC includes power control scheme in PCA. In these figures, we can find out a same conclusion for cases when there is no power control scheme applied, the block/refuse rate decreases as the ratio σ increases. But if σ is bigger than 0.7, the block/refuse rate increases rapidly. As σ gets bigger, the soft handoff area gets smaller and less soft handoff calls will be generated. Since soft handoff calls will get system resource from both of the cells involved in the handoff --- its home cell and active cell, less soft handoff calls are generated means that more system resource in each cell will be used for accepting incoming new calls and soft handoff calls, thus, the block rate of new voice/data calls shall decrease, so is expected to the soft handoff calls too. When σ gets bigger, the soft handoff area gets smaller and more system resource can be used for accepting incoming new calls or soft handoff calls. Because the soft handoff calls are given higher priorities than new calls, the soft handoff calls will get more chances to get admitted in this cell. Thus, the block rate of soft handoff calls shall decrease.

However, when the ratio σ gets even bigger than 0.7 or 0.75, more mobile stations will remain in the cell, while at the same time, more soft handoff calls still come in, both increase the interferences, this will lead to more blocks on incoming new calls or soft handoff calls., The optimal ratio of σ (the ratio of non-handoff area to the total cell area) in the cases of no power control is 0.6~0.7.

But, with power control scheme is implemented in the simulation system, the system shall execute power control at a rate of 20 Hz (800 Hz in real practice of IS-95 algorithm). The transmit power of every existing mobile station is adjusted quickly according to the received SIR at the home base station. The transmit power is decreased when the received SIR at the home base station is higher than the required SIR value, increased when the received SIR is lower than the required value. For the soft handoff calls, if both the power control commands from the two base stations involved in the handoff are power-up, the transmit power of this mobile station is increased by a fixed value (0.5 dB), otherwise, if either power control command is power-down, the transmit power of this mobile station is decreased. The goal of power control is to reduce the total transmit power of the system and maintain an acceptable QoS (SIR) for each mobile station. Because of the quick adjustment of transmit power, the received SIR of a mobile station at its home cell is maintained at a relatively stable level compared to the required SIR, the total transmit power of the system is reduced, and the interference in a cell is decreased too. Thus, more system resources can be used to accept incoming new calls or soft handoff calls. Furthermore, as explained in the above section, when the ratio of non-handoff area to the total cell area (σ) increases, more system resource can be used to accept incoming new calls or soft handoff calls, this also leads to the decrease of block/refuse rate.

From the figures 9-11, we can find that in cases with power control, the new voice call block rate, soft handoff voice call refuse rate and soft handoff voice call block rate keep decreasing as the ratio σ increases, until σ is bigger than 0.8. Because of the quick transmit power adjustment of every existing mobile station, the interference in a base station can be reduced, thus, the system resource available to accept incoming new calls or soft handoff calls is increasing, which leads to the drop of block/refuse rate. However, when σ is bigger than 0.8, more mobile stations will remain in this cell and more new calls or soft handoff calls still come in, which will increase the interference. But because the power control has reduced the whole transmit power of the system and thus reduced the interference, an incoming new call or soft handoff call will not apparently increase the interference in this cell, thus, the block/refuse rate will not increase greatly. With the observations above, we find that power control can effectively reduce the block/refuse rate for new calls or soft handoff calls in IS-95 algorithm, especially in the case of very restricted soft handoff area situations. From the simulation results above, an optical range of σ is 0.7~0.8 for the case of power control.

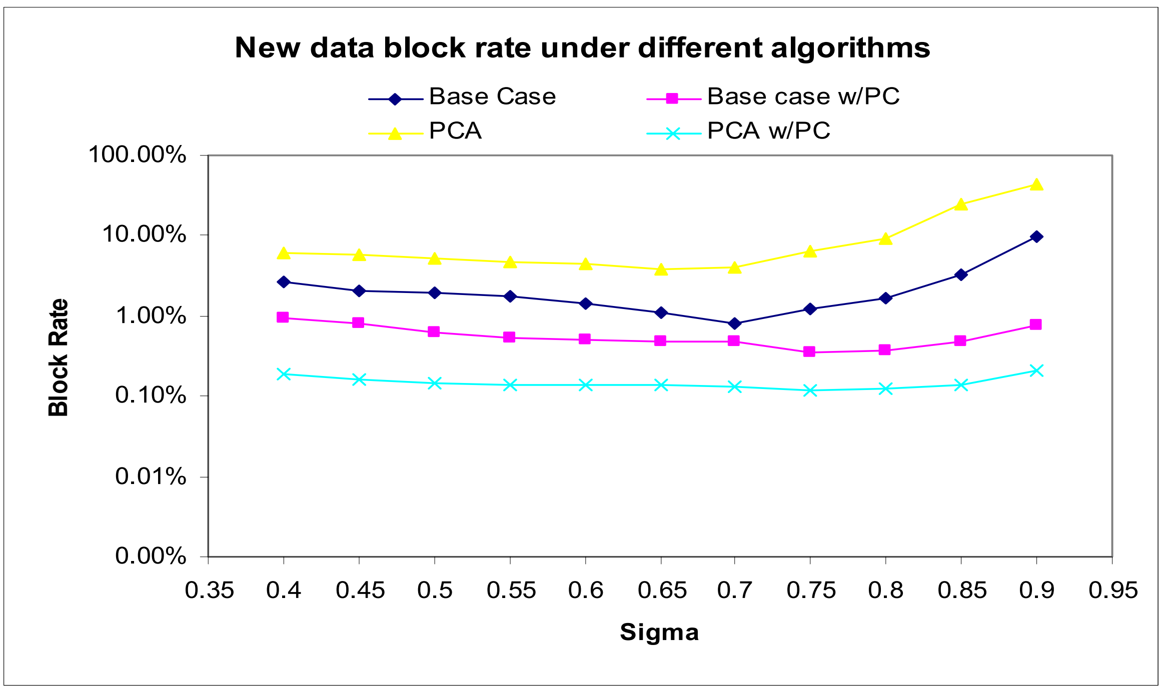


Fig. 12 New data block rate under different algorithms

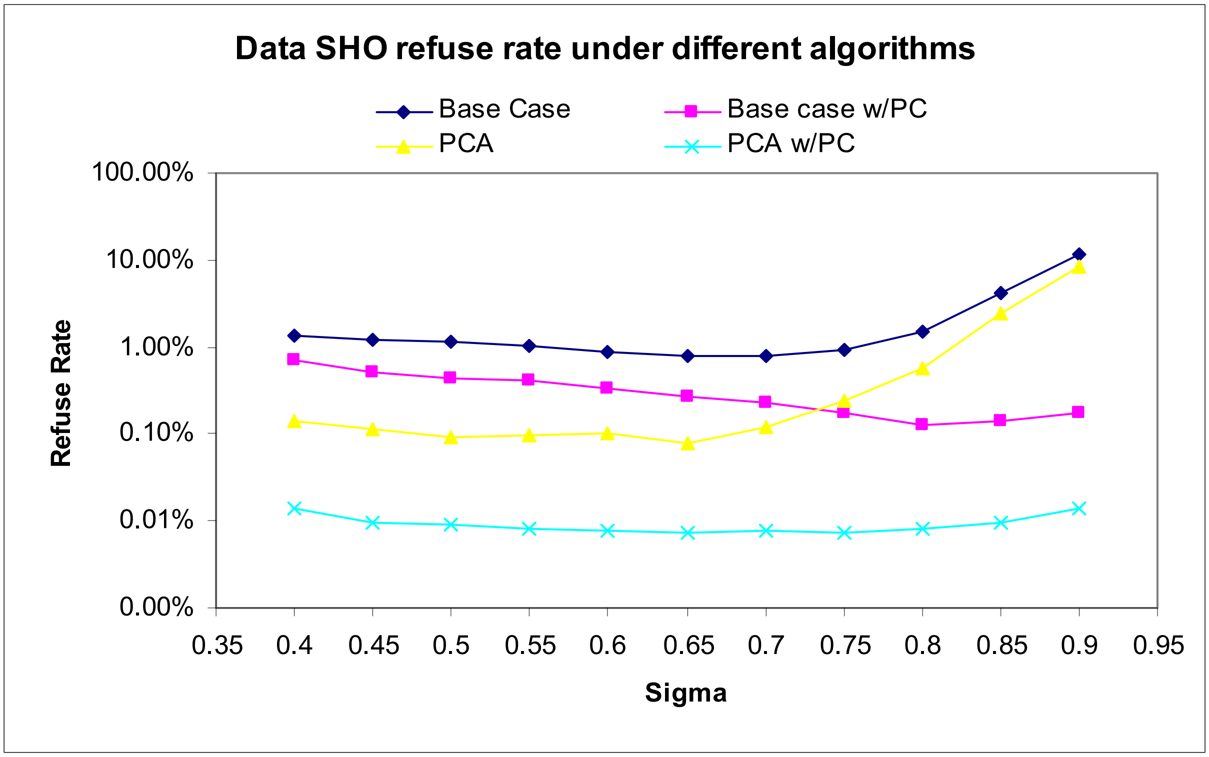
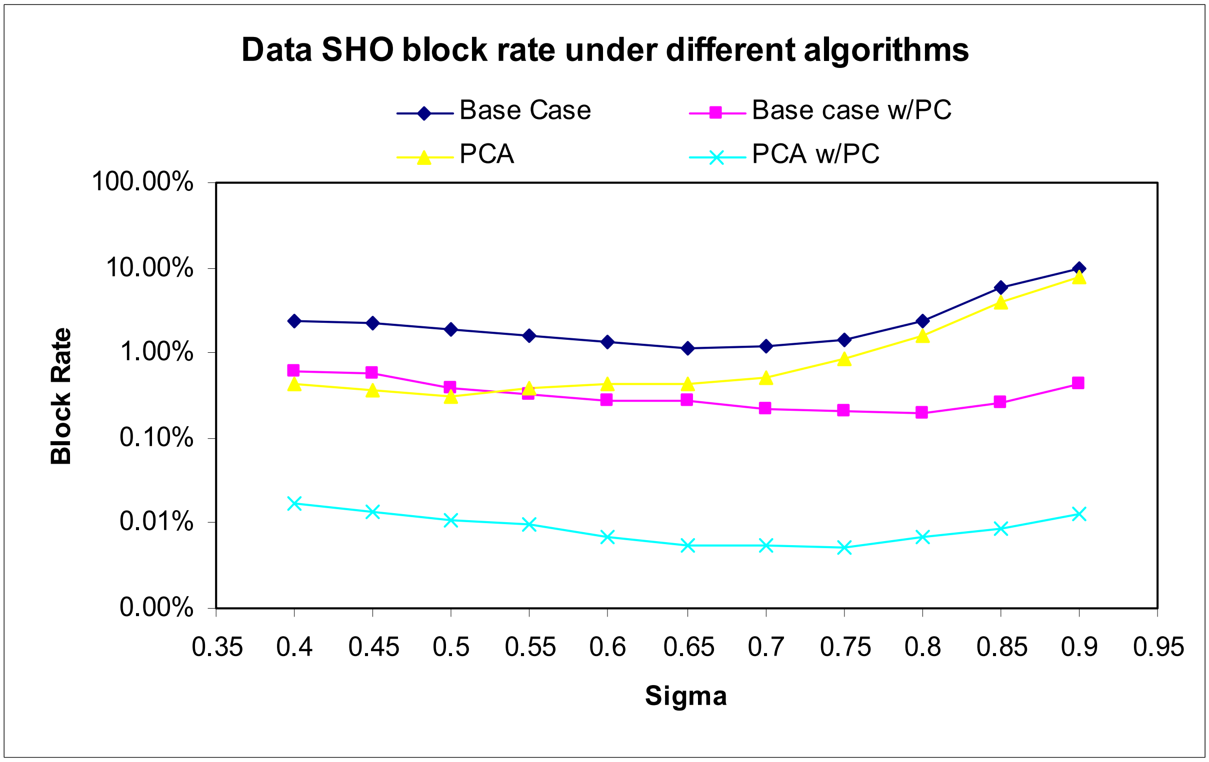


Fig. 13 Data SHO refuse rate under different algorithms



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ig. 14 Data SHO block rate under different algorithms

Similar to the performance of voice calls, when there is no power control implemented, the data calls block or refuse rate decreases as the ratio σ increases, until it reaches 0.7. After that, the data calls block or refuse rate increases rapidly. The reason can be explained in the previous section.

When power control is involved, similar to the voice calls, the data call block or refuse rate keeps decreasing. Similar to the base case and PCA case, when the ratio σ increases, the soft handoff area gets smaller, less soft handoff calls can be generated, more system resource can be used to accept incoming new call/soft handoff call, thus, the block/refuse rates of new call/soft handoff call decrease. With the quick power control, the transmit power of every existing mobile station is adjusted and the system interference is decreasing, thus, even more system resource is available to accept incoming new calls or soft handoff calls, compared to the cases without power control. But when σ is getting bigger than 0.75 or 0.8, the number of mobile stations that remain in the base station increases, even the power control has adjusted the system interference to a certain level, the incoming new call or soft handoff call will increase the interference, but not as much as it does in the cases without power control. Thus, the new call block rate, soft handoff refuse rate and soft handoff block rate will continue to drop until the ratio σ gets bigger than 0.8. According to the results in the figures, the optical range of the ratio σ will be 0.7~0.8.

Compare the different ranges of optical value of σ, we find that the power control can help to reduce the overlapping area of base stations. With power control, a smaller soft handoff area can be achieved.

From the previous discussion, we can find out that both power control and soft handoff prioritization (using soft handoff waiting queue and guard channel) can help to improve the system performance, in terms of new voice/data call block rate, soft handoff voice/data call refuse rate and soft handoff voice/data block rate. But from the Fig. 9-14, we can find that power control can improve the system performance close to the level when only soft handoff prioritization is applied, i.e. in PCA algorithm. Applying power control in the IS-95 algorithm can help to reduce the new call block rate dramatically, makes it even lower than the result of the PCA algorithm, which is using soft handoff prioritization with soft hand off waiting queue and guard channels.

In the case of power control under PCA algorithm with using of handoff waiting queue and guard channel, the effect of power control on new voice/data block rate, soft handoff refuse rate and soft handoff block rate is much more obvious than that of the cases under IS-95 call admission algorithm. Because of the using of handoff waiting queue and guard channel, the soft handoff calls are given even higher priorities than those in IS-95 algorithm. The performance is improved than that of IS-95 call admission algorithm.

However, when comparing the two CAC algorithm, when applying power control in the PCA algorithm, because of the using of handoff waiting queue and guard channel, the soft handoff calls gets more chances to get admitted compared to in the IS-95 algorithm with same power control scheme. The soft handoff calls waiting in a queue can have more chances to send handoff request again, while there are no such “second” chances in the IS-95 algorithm. Thus, the soft handoff block rate reduces and system performance improves in the PCA situation.

CONCLUSION

In this paper, researches have been focused on the effects of power control and soft handoff prioritization in uplink in multimedia DS-CDMA systems. Based on the different requirements of voice calls and data calls, the call admission algorithm can be improved using soft handoff prioritization: voice soft handoff waiting queue, data soft handoff waiting queue and soft guard channel. Compared to the IS-95 algorithm, this PCA algorithm helps reduce the soft handoff refuse/block rate significantly without increasing the new call block rate. With the help of power control, we can improve the system performance compared to that of the IS-95 algorithm. From the simulation results, we conclude: 1. with higher power control rate, the new call block rate, soft handoff refuse rate and soft handoff block rate can be reduced to a very low level. 2. When no power control applied, the optimal ratio of non-soft handoff area to the total cell area is 60~70%, which means the optimal soft handoff area is 30~40% of the total cell area. 3. power control can help to restrain the increase trend of new call block rate, soft handoff refuse rate and soft handoff block rate, no matter whether there is soft handoff prioritization or not. The optimal range of non-soft handoff area to the total cell area is 70~80%, which means a smaller overlapping of base stations, or a smaller soft handoff area is needed. 4. Power control has a significant effect on the system performance, when it is applied alone on the IS-95 algorithm, the system performance can be improved to the level of the performance when only handoff prioritization is applied. 5. With the combination of the power control with the soft handoff prioritization, we can get better system performance than that of only applying either of them.

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VITA

Wei Shi was born in a small town in the countryside of Jiangsu Province, China. With years of hard work like many other Chinese students did, he was admitted to University of Science & Technology of China, one of the top Chinese universities, with an exemption of any tests. He received his Bachelor Degree in Material Science & Technology in 1996. He worked for 4 years as an engineer in Shanghai Baosteel Group in the biggest city of China, Shanghai, where he also met and married his wife, who helped him a lot later.

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In the spare time, he likes reading, traveling. He has great interests in history and science developments. He is also a fan of sports such as Basketball, Tennis, F1, and Soccer. He is good at Ping-pong, and learning Tennis now.